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Full Length Research

CITY AND INDUSTRIAL EFFLUENT ANALYSIS AT FIVE SELECTED SITES IN MATHURA UP INDIA

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The present investigation is concerned with the determination of physico-chemical characteristics of Yamuna River water to assess the pollution load at five sampling points upstream to downstream including the quality of Water Works (Site I) supplied water (treated as Control) that of effluent sites *viz*., Masani Nala (Site II), Visharam Ghat (Site III), Yamuna Bridge (Site IV) and Sewage Farm (Site V). The physico-chemical analysis for city and industrial effluents was done in respect to colour, odour, transparency, turbidity, temperature, pH, total alkalinity, free CO_2, DO, BOD, COD, TSS, TDS, Cl^-, Ca^{2+}, Na^+, K^+, Mg^{2+}, SO_4^{2+}, inorganic PO_4^{--}, particulate PO_4^{--}, total dissolved PO_4^{--}, total Kjeldhal PO_4^{--}, NH_3-N, NO_3-N and heavy metals (Fe, Hg, Cd, Cr, Pb, As). Significant differences were noticed among all the parameters at 1% level of probability except heavy metals Hg and As when it was found to be significant at 5%. This study aims to study the potential water quality problem in Mathura. Further research is done to see water quality impact to raise higher crop yield. It is concluded from these studies that Yamuna River at Mathura has virtually become a Sewer Canal; receiving various drains dumping their contents; is grossly polluted due to city sewage, un-treated domestic wastes and also industrial effluents containing various salts including heavy metals which have extremely dangerous-life-threatening effects on aquatic biota and through food chains to animals and human populations.

Key words: Yamuna River Water, Physico-chemical Characteristics, Irrigation Impact.

INTRODUCTION

The River Yamuna, the largest tributary of River Ganga has been one of the most prominent and important rivers of India. Unfortunately, certain stretches of River Yamuna are grossly polluted because various urban centres like Delhi, Mathura, Agra etc., located on the banks of Yamuna River, draw fresh river water for various activities whereas in return almost the entire wastewater generated by these centres is disposed-off into the river. The Yamuna catchment area of the National Capital Territory, Delhi is 1% of the river's total catchment area, but contributes more than 50% of the pollutants found in the Yamuna (TERI, 2001). This is the prime reason for deterioration of Yamuna River

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water quality from urban agglomeration of up to Chambal River Confluence. The main reasons for Yamuna Pollution are untreated sewage, dumping of garbage, carcasses of dead bodies, industrial effluents, immersion of idols, and pollution added due to in stream usage of water. Urban agglomeration at National Capital Territory – Delhi is the major contributor of pollution in the Yamuna River followed by Mathura and Agra. About 85% of the total pollution in the river is contributed by domestic sources. The condition of river deteriorates further due to abstraction of significant amount of river water leaving almost no fresh water in the river essential to maintain the assimilation capacity of the river (CPCB, 2007).

With unsustainable advancement in developmental procedure water pollution has become a serious global problem (Sharma, 1976, 1977; Thakur, 2001; Singh, 2003; Sharma, 2004; Singh et al., 2008; Gautam, 2010; Parashar, 2011; Sharma et al., 2013; Snehlata, 2016; Parashar and Sharma, 2017; Pathak, 2017; Saraswat, 2017). All over the world people are facing problems due to water pollution and scientists are engaged with various aspects of water pollution and its management. Indus, Ganges and Yamuna Rivers of India; Nile of Egypt; Missouri River of USA; Great Slave Lake in North Canada; Huang Ho of China; Amazon of Brazil; Ob-Irtysh of USSR and Congo River of Central Africa are facing heavy pollution loads (Kudesia, 1998). In developing countries like India, fast and unplanned industrialization and urbanization led to a more alarming situation. In ancient Indian cities, establishments were not based on the sound environmental planning as majority of small scale industries were still located in the densely polluted city areas, thus various pollutants released from various sources are not allowed to disperse in water and assimilate. A similar situation prevails in Yamuna River in Mathura City too, where industries are located in and around the city. The City of Mathura, popularly known as "*Brajbhumi*" is one of the oldest and holiest living cities of the world that has acquired its eminence and great importance due to its unique combination of cultural, spiritual, religious and educational attributes (Sharma, 1976; Sharma, 2004; Parashar, 2011).

Though the problem of water pollution in Mathura is not as alarming as that of other cities but the increasing number of industries and ill-planned city sewage disposal poses a serious threat to the future of the city's life-line Yamuna. Rapid industrial development in the last few decades has added huge loads of pollutants to Yamuna River. In Mathura there are more than 250 industries in and around the city and from most of the industries, various pollutants are released directly into the river. Thus, even smaller concentration of pollutants becomes more injurious due to higher exposure durations. At present the population of the city is growing vigorously with mushrooming colonies without proper sewerage facilities. The city also abounds in narrow roads and lanes further intensifying the pollution problem (Parashar, 2011). Pollution of River Yamuna is increasing steadily between Mathura and Agra region due to rapid pollution growth, industrial proliferation, urbanization, increasing living standards and wide spheres of human activities. As per CSE, 2009 survey the river is devoid of water for virtually nine months.

Irrigation is the important use of Yamuna Water followed by domestic water supply, industrial and other uses. Therefore, water and wastewater analysis and their irrigational impact have become increasingly important for many reasons. Accordingly, a rapid and systematic examination of them is necessary. Also, a continuous deficit of good-quality fresh water implies that agriculture must use alternative resources such as saline water and sewage and industrial effluents for increasing agricultural production for ever-growing population besides abating pollution of our major river systems and other water-bodies (Parashar, 2011; Parashar and Sharma, 2017).

Water is relatively pure when formed, but when it enters atmosphere it absorbs gases, particularly oxygen and carbon dioxide. Upon reaching the earth, it dissolves the mineral matter with which it comes in contact. It can also be polluted with industrial, municipal and agricultural wastes. Surface water is generally softer and less concentrated than ground water. It often shows variations in its characteristics whereas ground water is characterized by essentially constant composition. Because of the higher mineral content, it is less preferable for domestic and industrial uses. As such, it becomes quite important to assess the water quality of the river for safe use. Thus, multiple sampling and analysis are needed to project a better picture regarding the quality of water (Manivasakam, 2000; Sharma, 2004; Parashar,

Figure1. Water works underground water storage tank.

Figure 2. Masani Nala flowing with city and industrial effluents (sii).

2011; Sharma et al., 2013; Snehlata, 2016; Parashar and Sharma, 2017). It is with this background, the present work was undertaken during summer 2011.

Objectives of the Study

The present study was an effort and aimed at detailed study of water quality in Mathura City in the State of Uttar Pradesh, India, with an attempt to see elsewhere its impact on plant growth and development (Parashar, 2011; Snehlata, 2016; Parashar and Sharma, 2017). Therefore, in order to provide eco-management plans to lessen water pollution load of the River Yamuna at Mathura the present research work was designed and proposed with the following objectives:

i. To determine the Physico-chemical analysis of effluents of Yamuna Water at Mathura
ii. To determine the Sources of water pollution in River Yamuna
iii. To evaluate elsewhere the effects of irrigation with effluents on plant development and metabolism so as to assess wastewater potential in increasing agricultural production with abatement of pollution in River Yamuna
iv. To assess the significant values of observed data and their correlation with other parameters
v. To make Recommendations to control water pollution for better eco-management of the River Yamuna at Mathura.

METHODOLOGY

Wastewater analysis

The major reason for Wastewater analysis is to decide its pollution potential and its perfect treatment. Different types of examinations (Physical, chemical, biological, microbiological and their effects on biota) of water are necessary as such the following studies were made:

I Selection of Study Sites and Survey of Major Pollution Sources

Selection of Study Sites: Total of five (5) sampling sites was selected in the city of Mathura including 'control site'.

***Site I – Water Works (Control Site) –*:** This site is located in extreme south of the city. Owing to absence of major pollution sources in this area this site was considered as 'control' (Figure 1).
***Site II Masani Nala –*:** This site is located on Mathura-Vrindavan Road near All India Radio, Mathura and is the major drain receiving city as well as industrial effluents. In this area major sources of pollution were noted (Figure 2).
***Site III Vishram Ghat –*:** This site is located at the centre of the city which is old commercial-cum-residential area heavily populated and is the main site for religious bathing and other activities of the people (Figure 3).
***Site IV Yamuna Bridge –*:** This site is located near the main cremation ground for the people of the city (Figures 4 -5).
***Site V Sewage Farm –*:** This site is Trans-Yamuna area about 6 km from the main city having sewage collection ponds with fields for sewage farming where different crops are grown especially seasonal vegetables (Figures 6-7).
Survey of the Major Pollution Sources: During survey of the Major Pollution Sources in the River

Figure 3. Floral Petals and other material being thrown into river at Vishram Ghat (Siii).

Figure 4. Coaltar black city sewage and industrial effluent rich river water with animal carcass being dumped near sewage farm.

Figure 5. Coaltar black effluent rich water with animal carcass being dumped in river water (siv).

Yamuna the main problem was found to be due to direct discharge of domestic waste and of industrial waste from the sari printing, silver-plating, imitation jewellery, polishing works, metal works and plumbing industries etc., into the River from Mathura's 19 major drains. As such the pollution sources of River Yamuna were categorized into (i) Point Sources such as – Domestic Pollution and Industrial Pollution; (ii) Non-point Sources such as Agricultural Pollution, Dumping of garbage and dead bodies, Immersion of idols, flower petals and other worship materials and Pollution due to in-stream uses (boating and navigation).

II Physico-Chemical Analysis OF The City And Industrial Effluents Affecting Yamuna River Water Quality

Three replicates each of one litre of the effluents (polluted) and Water Works tap water (control) were collected periodically in new plastic bottles. During the collection of effluents and water, samples were analysed for the physical properties like temperature, colour, odour and pH value at the time of sampling. The collected samples were stored in a cool, dark and dry place till analysis. Also care was taken to see that no contamination of the collection samples took place during transportation and storage. Necessary sampling precautions and specialized sampling instruments were used whenever needed (Meites, 1963; Michael, 1984) and water analysis was done for colour, odour, transparency, turbidity, temperature, pH, conductivity, alkalinity, free CO_2, DO, BOD, COD, TSS, TDS, Cl^- , Ca^{2+}, Na^+, K^+, Mg^{2+}, SO_4^{2+}, inorganic PO_4^{--}, particulate PO_4^{--}, total dissolved PO_4^{--}, total Kjeldhal PO_4^{--}, NH_3-N, NO_3-N, and heavy metals (Fe, Hg, Cd, Cr, Pb, As) with approved International Standard Test Methods for water/and wastewater analysis from Organizations like AOAC/APHA/ASTM/BIS/ISO etc., were followed (Table 1).

RESULTS

The investigation included the determination of physico-chemical characteristics of river water to assess the quantity as well as quality of major organic and inorganic pollutants at sampling points distributed upstream to downstream including the quality of **Water Works** (**Site I**) supplied water (treated as **Control**) and that of effluents from *the polluted sites* i.e., **Sites II** (**Masani Nala**), **Site III** (**Vishram Ghat**), **Site IV** (**Railway Bridge**) and **Site V** (**Sewage Farm**). The Sites II - V exhibited higher values for almost all the parameters as compared to

Figure 6. A view of sewage farm collection pond.

Figure 7. A view of sewage farm (sv).

those for water samples at **Site I** (the **Control Site**) during the entire period of investigation. Mean values of recorded physico-chemical parameters of five (5) sampling sites were tabulated and data has been presented in Tables 2 – 5. Significant differences were noticed among all the parameters at 1% level of Probability except heavy metals Hg and As when it was found to be significant at 5% (Tables 2 – 5). As depicted in Tables 2 –5**, Site II** (**Masani Nala**) and **Site V** (**Sewage Farm**) showed the highest peaks of almost all the parameters.

Table 2 Physico-chemical Analysis of effluents from five sampling sites at Mathura show results about water colour, odour, transparency, turbidity, temperature, conductivity, total suspended solids and total dissolved solids and their correlations as follows:

Colour: The maximum amounts of effluents were recorded in the water samples of **Site II** resulting in the appearance of black colour (a clear-cut indication of higher levels of pollutants), whereas a yellow colour observed at **Site V** samples. The **Sites III** and **IV** showed greenish colour (an evidence of the presence of high levels of phyto-planktons in the water). On the other hand, **Site I** (**Control Site**) showed clear transparent colour showing no effluents. Thus, objectionable colour observed at all the four sites except **Site I** was mainly due to the addition of city as well as industrial effluents discharged at these sites into the river water.

Odour: It was found to be odourless at the **Control Site** (**Site I**) but at the polluted sites water odour showed variation with Foul-pungent smell at the **Site II**, Stinking smell at the **Sites III** and **IV** and Stinking-pungent smell at the **Site V.**

Transparency: Water transparency also differed at different sites with Clear Transparency at the **Site I** (**Control Site**) followed by Blackish at the **Site II**, Greenish at the **Sites III** and **IV** and lastly Yellowish at the **Site V**. The transparency of water at different sites again becomes zero, an indicator of the presence of effluents as well as their density.

Turbidity: Coming to water turbidity it ranged from **2.000 – 11.000 NTU** at various sites with lowest value at the **Site I** (**Control Site** with **2.000 ± 0.000 NTU**), followed by **Site IV** (**6.367 ± 0.088 NTU**), **Site V** (**6.967 ± 0.033 NTU**), **Site III** (**7.000 ± 0.000 NTU**) and highest at **Site II** (**11.000 ± 0.000 NTU**). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 1% level of probability conforming to high pollution at these sites.

Temperature: Maximum temperature was recorded at **Site V** followed by **Site IV**, **Site III** and **Site II** whereas the minimum was at **Site I** (**Control Site**). All the polluted effluent sites exhibited higher values for temperature than the **Site I** (**Control Site** with **17.667 ± 0.333 ^{0}C**) samples which showed the lowest water temperature. Highest effluent temperature was recorded at the **Site V** (**33.000 ± 1.732 ^{0}C**) followed by **Site IV** (**31.667 ± 0.882 ^{0}C**), **Site III** (**26.667 ± 0.882 ^{0}C**) and least at the **Site II** (**24.667 ± 1.202 ^{0}C**). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 1% level of probability.

Conductivity: Conductivity was found to be very high (**412.00 – 933.00 mg/l**) with lowest in the **Site I** (**Control Site** with **412.000 ± 1.528 dsm^{-1}**) followed by **Site IV** (**634.000 ± 18.175 dsm^{-1}**), **Site III** (**683.000 ± 2.309 dsm^{-1}**), **Site II** (**863.000 ± 2.848 dsm^{-1}**) and highest (**933.000 ± 0.333 dsm^{-1}**) at the **Site V**. Statistically as compared to Site I (Control

Table 1. Methods of Physico-Chemical analysis of effluents from five sampling sites.

Physico-chemical Parameters	Analysis Method	References
Colour	Comparison method with standard colour solution and colour chart	Theroux et al., 1943; IWE, 1953; Michael, 1984; Trivedy and Goyal 1986; Manivasakam, 2000; APHA, 2005; Singh et al., 2008; Parashar, 2011 AOAC, 2012;
Odour	Smell	Trivedy and Goyal 1986; Manivasakam, 2000; APHA, 2005; Singh et al., 2008; Parashar, 2011; AOAC, 2012;
Transparency	Visual perception by immersing Secchi disc	Trivedy and Goyal 1986; Manivasakam, 2000; APHA, 2005; Singh et al., 2008; Parashar, 2011; AOAC, 2012;
Turbidity (NTU)	Peterson's Turbidity Meter Nephelometric	Trivedy and Goyal 1986; Manivasakam, 2000; APHA, 2005; Singh et al., 2008; Parashar, 2011; AOAC, 2012;
Temperature (^{0}C)	Thermometer	ISI, 1983; Trivedy and Goyal 1986; Manivasakam, 2000; APHA, 2005; Singh et al., 2008; Parashar, 2011; AOAC, 2012;.
pH	BDH Universal Indicator narrow range pH strips and pH meter	BSI, 1961; Michael, 1984; Trivedy and Goyal 1986; Manivasakam, 2000; APHA, 2005; Singh et al., 2008; Parashar, 2011; AOAC, 2012;
Conductivity (dSm^{-1})	Conductivity meter	Willard et al., 1958; Trivedy and Goyal 1986; Manivasakam, 2000; APHA, 2005; Singh et al., 2008; Parashar, 2011; AOAC, 2012;.
Total alkalinity (mg/l)	Potentiometric titration/colour indicator titration	Meites, 1963; Vogel, 1964; Trivedy and Goyal 1986; Manivasakam, 2000; APHA, 2005; Singh et al., 2008; Parashar, 2011; AOAC, 2012.
Free CO_2 (mg/l)	Phenolphthalein indicator titration method	IWE, 1953; Trivedy and Goyal 1986; Manivasakam, 2000; Thakur, 2001; Singh, 2003; Sharma, 2004; APHA, 2005; Singh et al., 2008; Parashar, 2011
DO (mg/l)	Winkler method	Trivedy and Goyal 1986; Manivasakam, 2000; APHA, 2005; Singh et al., 2008; Parashar, 2011; AOAC, 2012;
BOD (mg/l)	Three day BOD at 27 degree celsius	Theroux et al., 1943; Trivedy and Goyal 1986; BIS, 1993; Manivasakam, 2000; APHA, 2005; Singh et al., 2008; Parashar, 2011; AOAC, 2012;.
COD (mg/l)	Dichromate reflux	ASTM, 1972; Trivedy and Goyal 1986; Manivasakam, 2000; APHA, 2005; Singh et al., 2008; Parashar, 2011; AOAC, 2012;
TS (mg/l) TDS, TSS)	Gravimetric TSS = TS - TDS	Theroux et al., 1943; ISI, 1983; Trivedy and Goyal 1986; Manivasakam, 2000; APHA, 2005; Singh et al., 2008; Parashar, 2011.
Cl^- (mg/l)	Titrimetric (Argentometric)	Meites, 1963; Vogel, 1964; Trivedy and Goyal 1986; Manivasakam, 2000; APHA, 2005; Singh et al., 2008; Parashar, 2011; AOAC, 2012;
Ca^{2+} (mg/l)	Titrimetric (EDTA) oxalate method	Theroux et al., 1943; Connors, 1950; Trivedy and Goyal 1986; Manivasakam, 2000;; APHA, 2005; Singh et al., 1994; Parashar, 2011; AOAC, 2012;
Na^+ (mg/l)	Flame photometric method	Dean,1960; Trivedy and Goyal 1986; Manivasakam, 2000; APHA, 2005; Singh et al., 2008; Parashar, 2011; AOAC, 2012;

Table 1. Contd.

K^+ (mg/l)	**Flame Photometric method**	**Dean,1960; Trivedy and Goyal 1986; Manivasakam, 2000; APHA, 2005; Singh et al., 2008; Parashar, 2011**
Mg^{2+} (mg/l)	By difference between total hardness & calcium	Connors, 1950; Meites, 1963; Vogel, 1964; Trivedy and Goyal 1986; Manivasakam, 2000; APHA, 2005; Singh et al., 2008; Parashar, 2011; AOAC, 2012;
SO_4^{--} (mg/l)	Turbidi-metric method	Meites, 1963; Trivedy and Goyal 1986; Manivasakam, 2000; APHA, 2005; Singh et al., 2008; Parashar, 2011; AOAC, 2012;.
PHOSPHATE (mg/l) IP, PP, TDP, TKP)	Colorimetrically	Meites, 1963; Trivedy and Goyal 1986; Manivasakam, 2000; APHA, 2005; Singh et al., 2008; Parashar, 2011; AOAC, 2012;
NH_3-N (mg/l)	Colorimetric (NEDA method)	Theroux et al., 1943; Snell and Snell, 1949; Trivedy and Goyal 1986; Manivasakam, 2000; APHA, 2005; Singh et al., 2008; Parashar, 2011
NO_3^- -N (mg/l)	Colorimetric (NEDA method)	ASTM, 1972; Trivedy and Goyal 1986; Manivasakam, 2000; APHA, 2005; Singh et al., 2008; Parashar, 2011; AOAC, 2012;
Total Fe (mg/l)	Colorimetrically using thiocynate	Trivedy and Goyal 1986; Manivasakam, 2000; APHA, 2005; Parashar, 2011; AOAC, 2012;
Hg (mg/l)	Dithizone Method Flameless (cold vapour) atomic absorption	Sandell, 1959; ICMR, 1975; Trivedy and Goyal 1986; Manivasakam, 2000; Thakur, 2001; APHA, 2005; Parashar, 2011; AOAC, 2012;
Cr (mg/l)	Colorimetrically by s-Diphenyl Carbazid Atomic absorption spectrophotometer	Snell and Snell, 1949; ASTM, 1972; Trivedy and Goyal 1986; Manivasakam, 2000; Singh, 2003; APHA, 2005; Singh et al., 2008; Parashar, 2011; AOAC, 2012;
Cd (mg/l)	Dithizone Method	DOE, 1972; Trivedy and Goyal 1986 Manivasakam, 2000; APHA, 2005; Parashar, 2011; AOAC, 2012;
Pb (mg/l)	Dithizone Method	Trivedy and Goyal, 1986; Manivasakam, 2000; APHA, 2005; Parashar, 2011; AOAC, 2012;
As (mg/l)	Silver Diethyl Dithio Carbamate Method	NEERI, 1977; Trivedy and Goyal 1986; Manivasakam, 2000; APHA, 2005; Parashar, 2011; AOAC, 2012;

Site) all the four sites (II – V) showed highly significant differences at 1% level of probability conforming to higher salt concentration at these sites.

Total Suspended Solids: Total Suspended Solids (TSS) ranged from (**211.667 – 1212.000 mg/l**) with lowest values at the **Site I** (**Control Site** with **211.667 ± 0.667 mg/l**) and the highest at the **Site V** (**1212.000 ± 2.082 mg/l**) followed by the **Site II** (**1032.667 ± 2.333 mg/l**), **Site IV** (**312.333 ± 1.856 mg/l**) and lastly **Site III** (**222.667 ± 2.333 mg/l**). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 1% level of probability conforming to high concentration of suspended pollutants at these sites.

Total Dissolved Solids: *Total Dissolved Solids* (TDS) content was *lowest* in **Site I** (**Control Site** with **459.000 ± 2.309 mg/l**) and *highest* again at the **Site V** (**1971.333 ± 2.404 mg/l**) followed by **Site II** (**1882.333 ± 2.404 mg/l**), **Site IV** (**1391.333 ± 0.882 mg/l**) and **Site III** (**1298.667 ± 5.812 mg/l**). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 1% level of probability conforming to high concentration of soluble pollutants at these sites.

Table 3 shows the results about Physico-chemical analysis of effluents from sampling sites at Mathura; such as pH, DO, BOD, COD, free CO_2 and total

Table 2. Anova Table showing Mean, Standard Error, CV and CD of Physico-Chemical analysis of effluents from five sampling sites.

Physical Parameters	Sampling Sites					
	Water Works (Control Site) Site I	Masani Nala Site II	Vishram Ghat Site III	Yamuna Bridge Site IV	Sewage Farm Site V	Mean of Four Sites II to V
Colour	**Colourless**	**Blackish**	**Muddy**	**Muddy**	**Yellowish**	**-**
Odour	**Odourless**	**Foul-pungent**	**Stinking**	**Stinking**	**Stinking-pungent**	**-**
Transparency	**Clear**	**Blackish**	**Greenish**	**Greenish**	**Yellowish**	**-**
Turbidity (NTU)	2.000 ± 0.000	11.000 ± 0.000	7.000 ± 0.000	6.367 ± 0.088	6.967 ± 0.033	**7.833**
CD = 0.128	**SED ± 0.055**	**SEM ± 0.039**	**CV = 1.006**		**Significance 0.000000****	
Temperature (^{0}C)	17.667 ± 0.333	24.667 ± 1.202	26.667 ± 0.882	31.667 ± 0.882	33.000 ± 1.732	**29.000**
CD = 3.456	**SED ± 1.476**	**SEM ± 1.043**	**CV = 6.761**		**Significance 0.000043****	
Conductivity (mg/l)	412.000 ± 1.528	863.000 ± 2.848	683.000 ± 2.309	634.000 ± 18.175	933.000 ± 0.333	**778.25**
CD = 28.286	**SED ± 12.079**	**SEM ± 8.541**	**CV = 2.098**		**Significance 0.000000****	
TSS (mg/l)	211.667 ± 0.667	1032.667 ± 2.333	222.667 ± 2.333	312.333 ± 1.856	1212.000 ± 2.082	**694.75**
CD = 6.845	**SED ± 2.923**	**SEM ± 2.067**	**CV = 0.598**		**Significance 0.000000****	
TDS (mg/l)	459.000 ± 2.309	1882.333 ± 2.404	1298.667 ± 5.812	1391.333 ± 0.882	1971.333 ± 2.404	**1635.916**
CD = 11.306	**SED ± 4.828**	**SEM ± 3.414**	**CV = 0.422**		**Significance 0.000000****	

Values are arithmetic mean ± SEM of three replicates *, ** Significant at 5% P and 1% P respectively; ns-non significant.

alkalinity and their correlations as follows:

Hydrogen Ion Concentration: Hydrogen ion concentration (pH) showed lowest values at **Site II** (high acidic pH of **6.633 ± 0.088**) whereas at the other three polluted sites i.e., **Site III**, **IV** and **V** the pH values ranged from **8.100 ± 0.058** at **Site III** and **8.300 ± 0.115** at both the **Sites IV** and **V** showing an alkaline pH. On the other hand, at the **Site I** (**Control Site**) the pH was observed to be Neutral (**7.000 ± 0.000**). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 1% level of probability.

Dissolved Oxygen: Observations of Dissolved oxygen (DO) levels showed lowest values at the **Site I** (**Control Site** with **7.067 ± 0.033 mg/l**) with an *upward trend* at **Site III** (**14.000 ± 0.577 mg/l**), **Site IV** (**16.967 ± 0.145 mg/l**), **Site II** (**50.667 ± 1.202 mg/l**) and a *very high value* at **Site V** (**81.333 ± 0.882 mg/l**). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 1% level of probability conforming to high pollution at these sites.

Biological Oxygen Demand: Biological Oxygen Demand (BOD) levels also showed very high values with lowest at **Control Site** i.e., **Site I** (**Water Works** with **10.333 ± 0.333 mg/l**), with an upward trend at **Site IV** (**Yamuna Bridge** with **19.000 ± 1.155 mg/l**) and a slightly increased value at **Site III** (**Vishram Ghat** with **19.433 ± 0.120 mg/l**) and very-very high values at **Site II** (**Masani Nala** with **190.333 ± 0.882 mg/l**) and **Site V** (**Sewage Farm** with **211.333 ± 1.856 mg/l**). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 1% level of probability conforming to high pollution at these sites.

Chemical Oxygen Demand: Chemical Oxygen Demand (*COD*) values were also observed to be *high enough* ranging from *lowest values* at **Site I**

Table 3. Anova table showing Mean, Standard Error, CV and CD Physico-Chemical analysis of effluents from five sampling sites

Chemical Parameters	Sampling Sites					
	Water Works (Control Site) Site I	Masani Nala Site II	Vishram Ghat Site III	Yamuna Bridge Site IV	Sewage Farm Site V	Mean of Four Sites II to V
pH	7.000 ± 0.000	6.633 ± 0.088	8.100 ± 0.058	8.300 ± 0.115	8.300 ± 0.115	**7.833**
CD = 2.269	**SED ± 0.969**	**SEM ± 0.685**	**CV = 5.249**		**Significance 0.000000****	
DO (mg/l)	7.067 ± 0.033	50.667 ± 1.202	14.000 ± 0.577	16.967 ± 0.145	81.333 ± 0.882	**40.741**
CD = 2.076	**SED ± 0.886**	**SEM ± 0.627**	**CV = 3.193**	‘	**Significance 0.000000****	
BOD (mg/l)	10.333 ± 0.333	190.333 ± 0.882	19.433 ± 0.120	19.000 ± 1.155	211.333 ± 1.856	**109.941**
CD = 3.278	**SED ± 1.400**	**SEM ± 0.990**	**CV = 1.903**		**Significance 0.000000****	
COD (mg/l)	9.000 ± 0.058	390.667 ± 1.202	56.000 ± 1.000	34.000 ± 1.732	416.333 ± 0.667	**224.250**
CD = 3.722	**SED ± 1.589**	**SEM ± 1.124**	**CV = 1.074**		**Significance 0.000000****	
Free CO_2 (mg/l)	224.333 ± 1.764	180.000 ± 0.000	199.667 ± 0.882	203.667 ± 3.180	233.667 ± 2.028	**204.250**
CD = 6.259	**SED ± 2.673**	**SEM ± 1.890**	**CV = 1.572**		**Significance 0.000000****	
Total alkalinity (mg/l)	220.667 ± 1.202	179.000 ± 1.528	260.333 ± 0.882	252.000 ± 2.887	315.333 ± 2.728	**251.666**
CD = 6.337	**SED ± 2.706**	**SEM ± 1.913**	**CV = 1.350**		**Significance 0.000000****	

Values are arithmetic mean ± SEM of three replicates *, ** Significant at 5% P and 1% P respectively; ns- non significant.

Table 4. Anova table showing Mean, Standard Error, CV and CD Physico-Chemical analysis of effluents from five sampling sites.

Chemical Parameters	Sampling Sites					
	Water Works (Control Site) Site I	Masani Nala Site II	Vishram Ghat Site III	Yamuna Bridge Site IV	Sewage Farm Site V	Mean of Four Sites II to V
Cl^- (mg/l)	141.667 ± 2.404	718.667 ± 1.202	411.000 ± 1.528	511.000 ± 2.887	676.667 ± 1.856	**579.333**
CD = 7.343	**SED ± 3.136**	**SEM ± 2.217**	**CV = 0.781**		**Significance 0.000000****	
Ca^{2+} (mg/l)	60.333 ± 0.333	269.333 ± 1.764	219.333 ± 1.202	240.333 ± 0.882	286.667 ± 4.096	**253.916**
CD = 7.209	**SED ± 3.079**	**SEM ± 2.177**	**CV = 1.752**		**Significance 0.000000****	
Na^+ (mg/l)	20.22 ±1.53	254.13 ± 5.50	240.22 ± 4.82	196.33 ± 4.20	269.333 ± 1.764	**240.003**
CD = 5.266	**SED ± 3.231**	**SEM ± 2.284**	**CV = 1.815**		**Significance 0.000000****	
K^+ (mg/l)	9.49 ± 1.00	57.84 ± 1.57	43.440 ± 2.04	53.07 ± 1.11	72.00 ± 1.25	**56.587**
CD = 4.129	**SED ± 2.869**	**SEM ± 2.028**	**CV = 1.218**		**Significance 0.000000****	
Mg^{2+} (mg/l)	3.667 ± 0.333	223.333 ± 1.856	139.667 ± 0.882	262.667 ± 2.333	262.000 ± 2.517	**221.916**
CD = 6.418	**SED ± 2.741**	**SEM ± 1.938**	**CV = 1.883**		**Significance 0.000000****	
Inorganic P (mg/l)	0.100 ± 0.000	0.173 ± 0.009	0.113 ± 0.007	0.157 ± 0.009	0.190 ± 0.006	**0.158**
CD = 0.023	**SED ± 0.010**	**SEM ± 0.007**	**CV = 8.163**		**Significance 0.000062****	
Particulate P (mg/l)	0.200 ± 0.000	0.533 ± 0.088	0.433 ± 0.088	0.667 ± 0.033	1.200 ± 0.000	**0.708**

Table 4. Contd.

CD = 0.212	SED ± 0.091	SEM ± 0.064	CV = 18.306		Significance 0.000046**	
Total Dissolved P mg/l)	0.147 ± 0.012	0.817 ± 0.012	0.213 ± 0.007	0.243 ± 0.009	1.100 ± 0.000	**0.593**
CD = 0.032	**SED ± 0.013**	**SEM ± 0.010**	**CV = 3.280**		**Significance 0.000000****	
Total Kjeldhal P (mg/l)	1.100 ± 0.000	2.623 ± 0.018	1.717 ± 0.027	1.603 ± 0.009	2.150 ± 0.010	**2.023**
CD = 0.056	**SED ± 0.024**	**SEM ± 0.017**	**CV = 1.579**		**Significance 0.000000****	
SO_4^{--} (mg/l)	113.000 ± 2.082	313.000 ± 1.732	235.000 ± 1.528	271.667 ± 1.202	414.667 ± 1.667	**308.583**
CD = 6.107	**SED ± 2.608**	**SEM ± 1.844**	**CV = 1.185**		**Significance 0.000000****	
NH_3-N (mg/l)	0.000 ± 0.000	1.120 ± 0.010	0.407 ± 0.012	0.510 ± 0.012	1.240 ± 0.025	**0.819**
CD = 0.044	**SED ± 0.019**	**SEM ± 0.013**	**CV = 3.502**		**Significance 0.000000****	
NO_3^- -N (mg/l)	10.000 ± 0.577	20.333 ± 1.453	12.667 ± 1.453	15.000 ± 0.000	311.667 ± 1.202	**89.916**
CD = 3.911	**SED ± 1.670**	**SEM ± 1.181**	**CV = 2.766**		**Significance 0.000000****	

Values are arithmetic mean ± SEM of three replicates *, ** Significant at 5% P and 1% P respectively; ns-non significant.

(**Control Site** with **9.000 ± 0.058 mg/l**) followed with *upward values* at **Site IV** (**34.000 ± 1.732 mg/l**), **Site III** (**56.000 ± 1.000 mg/l**), **Site II** (**390.667 ± 1.202 mg/l**) and *highest* at **Site V** (**416.333 ± 0.667 mg/l**). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 1% level of probability conforming to high pollution at these sites.

Free Carbon Dioxide: Free Carbon dioxide showed the least value at **Site III** (**199.667 ± 0.882 mg/l**) and the highest values were recorded at **Site V** (**233.667 ± 2.028 mg/l**) and the **Sites II** (**180.000 ± 0.000 mg/l**), **IV** (**203.667 ± 3.180 mg/l**) and **Site I** (**Control Site** with **224.333 ± 1.764 mg/l**) fell between the two extremes and showed an enhancement over **Site III**, **Site II** and the **Site IV** only lagging behind the **Site V**. Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 1% level of probability conforming to high pollution at these sites.

Total Alkalinity: Total alkalinity was found to be lowest at **Site II** (**179.000 ± 1.528 mg/l**) followed by **Site I** (**Control Site** with **220.667 ± 1.202 mg/l**), **Site IV** (**252.000 ± 2.887 mg/l**), **Site III** (**260.333 ± 0.882 mg/l**) and the highest at **Site V** (**315.333 ± 2.728 mg/l**) (Table 3). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 1% level of probability conforming to high pollution at these sites.

Table 4; Physico-chemical Analysis of effluents from sampling sites at Mathura show results about Cl^-, Ca^{2+}, Na^+, K^+, Mg^{2+}, SO_4^{2+}, Inorganic P, Particulate P, Total Dissolved P, Total Kjeldhal P, NH_3-N and NO_3-N and their correlations as follows:

Chloride Ions: Regarding the *Anion* (-ve ions) *Chloride ions* (Cl^-) the variation was quite observable with *lowest* being at **Site I** (**Control Site** with **141.667 ± 2.404 mg/l**) followed *upwardly* at the **Site III** (**411.000 ± 1.528 mg/l**), **Site IV** (**511.000 ± 2.887 mg/l**), **Site V** (**676.667 ± 1.856 mg/l**) and the *highest* at the **Site II** (**718.667 ± 1.202 mg/l**). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 1% level of probability conforming to high pollution at these sites.

Likewise, Cations (+ve ions) Calcium ions (Ca^{2+}), Sodium ions (Na^+), Potassium ions (K^+) and Magnesium ions (Mg^{2+}) also showed variable trends at various sites with lowest values at **Site I** (**Control Site**):

Calcium Ions: Calcium ions (Ca^{2+}) at **Site I** (**Control Site** with **60.333 ± 0.333 mg/l**) were the least followed upwardly at **Site III** (**219.333 ± 1.202 mg/l**), **Site IV** (**240.333 ± 0.882 mg/l**), **Site II** (**269.333 ± 1.764 mg/l**) and highest at **Site V** (**286.667 ± 4.096 mg/l**). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed

highly significant differences at 1% level of probability conforming to high pollution at these sites.

Sodium Ions: Sodium ions (Na^+) at **Site I** (**Control Site** with **20.220 ± 1.530 mg/l**) were the least followed upwardly at **Site IV** (**196.333 ± 4.200 mg/l**), **Site III** (**240.220 ± 4.820 mg/l**), **Site II** (**254.133 mg/l**) and highest at **Site V** (**269.333 ± 1.764 mg/l**). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 1% level of probability conforming to high pollution at these sites.

Potassium Ions: Potassium ions (K^+) at **Site I** (**Control Site** with **9.490 ± 1.000 mg/l**) were the least followed upwardly at **Site III** (**43.440 ± 2.040 mg/l**), **Site IV** (**53.070 ± 1.111 mg/l**), **Site II** (**57.840 ± 1.570 mg/l**) and highest at **Site V** (**72.000 ± 1.250 mg/l**). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 1% level of probability conforming to high pollution at these sites.

Magnesium Ions: Magnesium ions (Mg^{2+}) at **Site I** (**Control Site** with **3.667 ± 0.333 mg/l**) were the least followed upwardly at **Site III** (**139.667 ± 0.882 mg/l**), **Site II** (**223.333 ± 1.856 mg/l**), **Site V** (**262.000 ± 2.517 mg/l**) and highest at **Site IV** (**262.667 ± 2.333 mg/l**). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 1% level of probability conforming to high pollution at these sites.

Sulphate Ions: Sulphate ions (SO_4^{2+}) at **Site I** (**Control Site** with **113.000 ± 2.082 mg/l**) were the least followed upwardly at **Site III** (**235.000 ± 1.528 mg/l**), **Site IV** (**271.667 ± 1.202 mg/l**), **Site II** (**313.000 ± 1.732 mg/l**) and highest at **Site V** (**414.667 ± 1.667 mg/l**). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 1% level of probability conforming to high pollution at these sites.

Inorganic Phosphate: Inorganic Phosphate at **Site I** (**Control Site** with **0.100 ± 0.000 mg/l**) was the least followed upwardly at **Site III** (**0.113 ± 0.007 mg/l**), **Site IV** (**0.157 ± 0.009 mg/l**), **Site II** (**0.173 ± 0.009 mg/l**) and highest at **Site V** (**0.190 ± 0.006 mg/l**). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 1% level of probability conforming to high pollution at these sites.

Particulate Phosphate: Particulate Phosphate at **Site I** (**Control Site** with **0.200 ± 0.000 mg/l**) was the least followed upwardly at **Site III** (**0.433 ± 0.008 mg/l**), **Site II** (**0.533 ± 0.008 mg/l**), **Site IV** (**0.667 ± 0.033 mg/l**) and highest at **Site V** (**1.200 ± 0.000 mg/l**). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 1% level of probability conforming to high pollution at these sites.

Total Dissolved Phosphate: Total Dissolved Phosphate at **Site I** (**Control Site** with **0.147 ± 0.012 mg/l**) was the least followed upwardly at **Site III** (**0.213 ± 0.007 mg/l**), **Site IV** (**0.243 ± 0.009 mg/l**), **Site II** (**0.817 ± 0.012 mg/l**) and highest at **Site V** (**1.100 ± 0.000 mg/l**). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 1% level of probability conforming to high pollution at these sites.

Total Kjeldhal Phosphate: Total Kjeldhal Phosphate at **Site I** (**Control Site** with **01.100 ± 0.000 mg/l**) was the least followed upwardly at **Site IV** (**1.603 ± 0.009 mg/l**), **Site III** (**1.717 ± 0.027 mg/l**), **Site V** (**2.150 ± 0.010 mg/l**) and highest at **Site II** (**2.623 ± 0.018 mg/l**). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 1% level of probability conforming to high pollution at these sites.

Ammonical Nitrogen: Ammonical Nitrogen (NH_3-N) was not detected at **Site I** (**Control Site**), however, the lowest amount was found at **Site III** (**0.407 ± 0.012 mg/l**) followed upwardly at **Site IV** (**0.510 ± 0.012 mg/l**), **Site II** (**1.120 ± 0.010 mg/l**) and highest at **Site V** (**1.240 ± 0.025 mg/l**). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 1% level of probability conforming to high pollution at these sites.

Nitrate Nitrogen: Nitrate Nitrogen (NO_3-N) at **Site I** (**Control Site** with **10.000 ± 0.577 mg/l**) was the least followed upwardly at **Site III** (**12.667 ± 1.453 mg/l**), **Site IV** (**15.000 ± 0.000 mg/l**), **Site II** (**20.333 ± 1.453 mg/l**) and highest at **Site V** (**311.667 ± 1.202 mg/l**) (Table 4). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 1% level of probability conforming to high pollution at these sites.

Table 5; Physico-chemical Analysis of effluents from sampling sites at Mathura shows results about Heavy Metals and their correlations as follows:

Table 5. Anova analysis showing Mean, Standard Error, CV and CD Physico-Chemical analysis of effluents Physico-Chemical analysis of effluents from five sampling sites.

Chemical Parameters Heavy metals	Sampling Sites					
	Water Works (Control Site) Site I	Masani Nala Site II	Vishram Ghat Site III	Yamuna Bridge Site IV	Sewage Farm Site V	Mean of Four Sites II to V
Fe (mg/l)	0.100 ± 0.000	0.267 ± 0.033	0.100 ± 0.000	0.167 ± 0.033	1.400 ± 0.058	**0.483**
CD = 0.121	**SED ± 0.052**	**SEM ± 0.037**	**CV = 15.552**		**Significance 0.000000****	
Hg (mg/l)	0.000 ± 0.000	0.067 ± 0.020	0.037 ± 0.012	0.023 ± 0.009	0.083 ± 0.015	**0.053**
CD = 0.048	**SED ± 0.020**	**SEM ± 0.014**	**CV = 59.682**	**'F'- value 5.32**	**Significance 0.021763***	
Cr (mg/l)	0.000 ± 0.000	0.223 ± 0.020	0.090 ± 0.017	0.073 ± 0.015	0.250 ± 0.021	**0.159**
CD = 0.046	**SED ± 0.019**	**SEM ± 0.014**	**CV = 18.750**	**'F'- value 58.93**	**Significance 0.000006****	
Cd (mg/l)	0.000 ± 0.000	7.337 ± 0.337	4.033 ± 0.598	3.153 ± 0.640	7.107 ± 0.647	**5.406**
CD = 1.327	**SED ± 0.567**	**SEM ± 0.401**	**CV = 16.049**	**'F'- value 57.53**	**Significance 0.000006****	
Pb (mg/l)	0.000 ± 0.000	0.257 ± 0.009	0.167 ± 0.015	0.160 ± 0.010	0.297 ± 0.033	**0.220**
CD = 0.054	**SED ± 0.023**	**SEM ± 0.016**	**CV = 16.020**	**'F'- value 49.42**	**Significance 0.000011****	
As (mg/l)	0.000 ± 0.000	0.873 ± 0.055	0.367 ± 0.033	0.383 ± 0.313	0.597 ± 0.037	**0.555**
CD = 0.454	**SED ± 0.194**	**SEM ± 0.137**	**CV = 53.506**	**'F'- value 5.51**	**Significance 0.019818***	

Values are arithmetic mean ± SEM of three replicates *, ** Significant at 5% P and 1% P respectively; ns-non significant.

Regarding the heavy metals, none were detected at **Site I** (**Control Site**) whereas variable concentration of the heavy metals, Fe, Hg, Cr, Cd, Pb and As were detected in the **effluent samples** in the waters of River Yamuna from the **Sites II**, **III**, **IV** and **V**. Peaks were observed in samples collected downstream of Site II (Masani Nala), Site III (Vishram Ghat), Site IV (Yamuna Bridge) and Site V (Sewage farm) indicating the anthropogenic nature of the contamination. The river receives wastewater with city sewage and industrial effluents from Site II and 18 other drains drains downstream to Site V (Sewage Farm). Average heavy metal concentration at different locations in the river water varied in the order of *Cd>As >Fe>Pb>Cr>Hg.*

Iron: Iron at **Site I** (**Control Site** with **0.100 ± 0.000 mg/l**) and at **Site III** (**0.100 ± 0.000 mg/l**) were the least followed upwardly at **Site IV** (**0.167 ± 0.033 mg/l**), **Site II** (**0.267 ± 0.033 mg/l**) and highest at **Site V** (**1.400 ± 0.058 mg/l**). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 1% level of probability conforming to high pollution at these sites.

Mercury: Mercury (Hg) was detected in least concentration at the **Site IV** (**0.023 ± 0.009 mg/l**) followed upwardly at **Site III** (**0.037 ± 0.012 mg/l**), **Site II** (**0.067 ± 0.020 mg/l**) and highest at **Site V** (**083 ± 0.015 mg/l**). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 5% level of probability conforming to high pollution at these sites.

Chromium: Likewise, Chromium (Cr) was detected in least concentration at the **Site IV** (**0.073 ± 0.015 mg/l**) followed upwardly at **Site III** (**0.090 ± 0.017 mg/l**), **Site II** (**0.223 ± 0.020 mg/l**) and highest at **Site V** (**0.250 ± 0.021 mg/l**). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 1% level of probability conforming to high pollution at these sites.

Cadmium: Heavy metal Cadmium (Cd) was detected in least concentration at the **Site IV** (**3.153 ± 0.640 mg/l**) followed upwardly at **Site III** (**4.033 ± 0.598 mg/l**), **Site V** (**7.107 ± 0.647 mg/l**) and highest at **Site II** (**7.337 ± 0.337 mg/l**). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 1% level of probability conforming to high pollution at these sites.

Lead: Lead (Pb) was detected in least concentration at the **Site IV** (**0.160 ± 0.010 mg/l**) followed upwardly at **Site III** (**0.167 ± 0.015 mg/l**), **Site II** (**0.257 ± 0.009 mg/l**) and highest at **Site V** (**0.297 ± 0.033 mg/l**). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 1% level of probability conforming to high pollution at these sites.

Arsenic: Arsenic (As) was detected in least concentration at **Site III** (**0.367 ± 0.033 mg/l**) followed upwardly at **Site IV** (**0.383 ± 0.313 mg/l**), **Site V** (**0.597 ± 0.037 mg/l**) and highest at **Site II** (**0.873 ± 0.055 mg/l**). Statistically as compared to Site I (Control Site) all the four sites (II – V) showed highly significant differences at 5% level of probability conforming to high pollution at these sites.

DISCUSSION

City sewage and industrial effluents, containing various colours, tastes, odours, organic and inorganic compounds, acids, alkalies, salts, heavy metals and other materials in dissolved and suspended forms, are normally considered as the main pollutants in water-bodies. Knowledge of physico-chemical and biological properties of the effluents is very essential for understanding their effects on the biota and soil of the ecosystem receiving such discharges from the city sewage and industries. The increase in dissolved, suspended and total solids of water deteriorates the suitability of its quality which may prove toxic to the plants and ultimately to all animals and human being through food chains. As these solids require huge amounts of biochemical oxygen for their decomposition the effluents receiving soils show oxygen deficiency and may adversely affect the growth activity of the plants. The suitability of water for irrigation is determined by the amount and kind of salts present therein. A continuous supply of such effluents may also lead to increased level of salinity and heavy metals which can prove toxic for growth of plants in due course of time (Trivedy and Goyal 1986; Manivasakam, 2000; Thakur, 2001; Singh, 2003; Singh et al., 2008; Parashar, 2011; Sharma et al., 2013; Snehlata, 2016; Parashar and Sharma, 2017; Pathak, 2017; Saraswat, 2017).

Mathura located on the bank of River Yamuna is visited by millions of people throughout the year from the country and all over the world (Sharma, 1976) therefore the problem of garbage and sewage disposal is very much deplorable added with industrial wastes all of which are dumped at various places through 19 major drains in the River (CSE, 2007). All these factors cause a severe deterioration of river water quality. Water quality of drains entering Yamuna River at Mathura has been investigated by a number of researchers and various agencies show that the river water is highly polluted containing a large number of toxic metals coming out of the city sewage and various industrial outlets (Sharma, 1976; Thakur, 2001; Sharma, 2004; CPCB, 2006; CSE, 2007; Kumar et al., 2011; Parashar, 2011; Yadav and Rajawat, 2011; Gupta et al., 2013; Sharma et al., 2013; Singh et al., 2013; Yadav and Mishra, 2014; Kumar et al., 2016; Singh and Kumar, 2016; Snehlata, 2016). Further, Yamuna River and wells are the main sources for drinking, bathing and other domestic and agricultural purposes etc. These sources are often polluted by domestic sewage, human excreta and excreta of birds and animals, plant debris etc. Yamuna water is also severely polluted by municipal and industrial wastes. A distinction between industrial and municipal wastes however, is difficult to make because many industrial plants, especially sari, silver and chemical industries in the city area discharge their wastes directly into municipal sewer systems. As a result, what is referred to as municipal wastes, is to a large extent industrial wastes and trade effluents from large and small industrial units besides containing organic pollutants. These also contain specific toxic substances that are very dangerous to human and animal health and also kill bacteria, aquatic plants and animals living in the river, there are frequent reports in media of thousands of fish being killed in Yamuna. Besides, industry also poses another important pollution problem – heat, warmer water being poured into river absorbing less oxygen and slows down natural decomposition of organic matter

(Sharma, 1976; Thakur, 2001; Sharma, 2004; Parashar, 2011; Snehlata, 2016).

Present investigation showed the poor quality of Yamuna River water due to the presence of treated and untreated sewage wastes and continuous mixing of industrial effluents. In our study the deteriorating quality of river water has been studied at four selected sites (Sites II to V) along with control site (Site I) for its physico-chemical parameters with effects elsewhere on soils and ultimately on growth and metabolism of major crops of the region to assess the potential of wastewater after dilution for some use in increasing the agricultural production and abatement of river pollution (Sharma, 2004; Parashar, 2011; Snehlata, 2016; Parashar and Sharma, 2017).

The rapid fluctuation in different physico-chemical parameters studied, directly or/and indirectly indicate the changes in the quality of river water. The proper analysis and correlation of these parameters enabled us to characterize the degree of water pollution and elsewhere its ultimate impact on vegetation and ultimately through food chain on animals and human being. In the present investigation water quality in Mathura has been studied in relation to various kinds of pollutants discharged in the body of Yamuna River from various sources such as human or inhuman. The nature of different pollutants in wastewater varies greatly according to the quality of their sources from where they are discharged into the river. The investigation included the determination of physico-chemical characteristics of river water to assess the quantity as well as quality of major organic and inorganic pollutants at sampling points distributed from upstream to downstream including the quality of Water Works (Site I) supplied water (treated as Control) and that of Sewage Farm (Site V). It was clearly observed that the various parameters studied vary considerably among the different sites observed as Sites II, III, IV and V exhibited higher values for almost all the parameters as compared to those for water samples at Control Site i.e., Site I during the entire period of investigation. The sources of odourous substances in potable water have been recorded by Thakur (2001), Sharma (2004), Singh (2003), Singh et al., (2008), Parashar (2011), Sharma et al., (2013); Snehlata (2016) Parashar and Sharma (2017). The water odour which is an important criterion of water to determine the basic frame for water quality and in chemical sense it depends upon the actual contact of the stimulating substances with appropriate human receptor cells. The odour in the natural water may be caused due to (a) growth of micro-organisms in water which releases odour producing substances, (b) with the decomposition of dead organic debris such as leaves, grasses and other aquatic vegetation, (c) growth of slime organisms viz., moulds or fungi, (d) presence of volatile substances and (e) reduction of sulphate to sulphides under the anaerobic conditions. As such water quality in River Yamuna observed at various sites showed foul-stinking to stinking-pungent smell, except Control site, owing to higher levels of TDS, chlorides, sulphates, SS and total hardness with 120 million litres of untreated muck being dumped daily by Delhi's sewerage system. Truly, called a 'Sewage Canal' Yamuna has become one of the most polluted rivers in the world (CSE, 2007).

The colour of water is also a good indicator of the presence of effluents. In the present investigation it was found that most of the industries located in Mathura (printing, dyeing, silver polishing, supari, chemical industries etc.,) discharge their effluents in the Yamuna River through various drains, therefore, the five sites studied except the Site-I showed different colours in the water. The maximum amounts of effluents were recorded in the water samples of Site II resulting in the appearance of black colour (a clear-cut indication of higher levels of pollutants), whereas a yellow colour observed at Site V samples. The Sites III and IV showed greenish colour (an evidence of the presence of high levels of phyto-planktons in the water). On the other hand, Site I showed a clear transparency showing absence of effluents. Thus, objectionable colour observed at all the four sites except Site I was mainly due to the addition of city as well as industrial effluents discharged at these sites. The transparency of water at different sites again becomes zero, an indicator of the presence of effluents as well as their density. The description presented in the present investigation reveals that the transparency varied with different sites from bluish-black to yellowish-green tinge except at Site I.

Temperature is one of the most important physical factors which influence the major processes of fresh water resources. Water temperature variation was due to changing atmospheric temperature (Kumar et al., 2016). The reproduction, development and growth of biota is also influenced by temperature

which in turn together with other physical factors exercises a significant control over the distribution of gases, nutrients and other similar biogenic processes in water. Thakur (2001), Sharma (2004), Parashar (2011), Snehlata (2016) reported that in downstream there would be an increase in temperature of the river water with the degree of pollution with city and industrial wastes being discharged into the river. The other factors which affect the water temperature are the degree of insulation, wind velocity, humidity of the atmosphere and the nutrient interference between ground and river water. However, the solar radiation together with other physical factors exercises a significant role on the water temperature and thermal stratification of any water body. Maximum temperature was recorded at Site V followed by Sites IV, III and II whereas the minimum was in the Site I (Control Site). The present study is in conformity with the earlier findings (Rai, 1974a, b; Yadav and Saxena, 1987; Thakur, 2001; Sharma, 2004; Kumar et al., 2011; Parashar, 2011; Yadav and Rajawat, 2011; Sharma et al., 2013; Singh et al., 2013; Kumar et al., 2016; Snehlata, 2016) which reported water temperature variations contaminated by effluents from various types of industries. Our results clearly revealed that the presence of effluents from city and industrial discharges is the major cause of rising temperature. It was interesting to note that water temperature was higher at Sites IV and V owing to entry of heated effluents discharged by the increasing population of the city along with industrial development. With the rise of temperature there is decline in the DO levels. Also a rise in temperature leads to the speeding up of the physico-chemical reactions in water reducing the solubility of gases as such temperature showed strong positive correlation with turbidity, BOD, COD, DO, TSS and TDS and a mild correlation with pH, ammonia and nitrates. The strong correlation of temperature with turbidity, DS and SS is due to the quick evaporation of water when temperature is high. In concentrated water their density becomes high and leads to high turbidity as is shown by a number of workers (Thakur, 2001; Sharma, 2004; Parashar, 2011; Snehlata, 2016). The temperature, however, showed negative relation with DO which might probably be due to the fact that solubility of gases is lowered with rise in temperature (Thakur, 2001; Sharma, 2004; Kumar et al., 2011; Parashar, 2011; Yadav and Rajawat, 2011; Sharma et al., 2013; Singh et al., 2013; Kumar et al., 2016; Snehlata, 2016).

The pH is another most important factor that influences the rate of biochemical conversion which can be used as indictor parameter in the detection of any serious deterioration of the aquatic environment as a consequence of pollution. It is equally useful in water supplies where surface water is used as raw water source. Since pH controls the whole process of water treatment such as coagulation, disinfection, softening and corrosion control therefore its determination becomes quite important (Luklema, 1969, 1971; Alwan, 2008). The determination of water pH serves as a valuable indicator of the acidic or alkaline nature of the pollutants which changes significantly owing to addition of sewage and industrial effluents. The production of ammonia from the untreated waste makes the water alkaline. An interesting observation was seen in the variation of pH values as the pH of Site I (the Control Site) was found to be neutral (7.000 ± 0.000) whereas rest of the water samples (Sites III, IV and V) except Site II (where slight-acidic water was collected) showed an alkaline trend, with little differences, because of higher sewage mixing at these sites and had also received the direct outlets of several sari printing industries using caustic soda ($NaCO_3$). pH values (7.0 to 8.10) of all sites except Site II (Masani Nala) where it was recorded 6.633 ± 0.088 were close to recommended value (6.8-8.5) of water for drinking purpose. It was noticed that the pH value of the water appears to be dependent upon the relative quantities of calcium, carbonates and bicarbonates (Sharma et al., 2013). The water trends to be more alkaline when it possessed carbonates (Jain et al., 2000; Khanna and Bhutani, 2003).The data suggested a relationship between pH and temperature where temperature showed a slight upward trend was also observed in pH values. Further, pH showed its positive correlation with all the parameters except the DO which might probably be due to the fact that oxygen reduces the alkalinity of ammonical wastes (ASTM, 1972; Dakshini and Soni, 1979; Mathur et al., 1987; Thakur, 2001; Singh, 2003; Sharma, 2004; Singh et al., 2008; Sharma et al., 2013; Parashar, 2011; Snehlata, 2016). Our results observed in the present study are in accordance with the findings of other workers (Kumar et al., 2011; Yadav and Rajawat, 2011; Singh et al., 2013; Kumar et al., 2016).

Turbidity is one of the common ways of measuring the extent of water pollution. Untreated and un-decomposed organic matter, sewage and industrial wastes generally cause turbidity causing a soapy froth on water surface. Turbidity is a striking physical characteristic of sewage and most of the industrial wastes in their degree of cloudiness which is related to the amount of suspended or colloidal matter in the water-body affecting the clarity and penetration of light and can reduce the effectiveness of chlorination resulting in difficulty in meeting BOD and suspended solid limits (Daphne et al., 2011; Meozzi, 2011). Turbidity reduces the light penetration deep in the water adversely affecting the photosynthetic activity of submerged vegetation thereby reducing the self-purification capacity of river water. The suspended solids increase the turbidity of river water (Thakur, 2001; Singh, 2003; Sharma, 2004; Singh et al., 2008; Parashar, 2011; Snehlata, 2016). The muddy water of rivers in the rainy season is always due to suspended soil eroded during floods as also been observed by Sharma (1976), Thakur (2001), Sharma (2004), Kumar et al., (2011), Parashar (2011), Yadav and Rajawat (2011), Gupta et al., (2013), Singh et al., (2013), Sharma et al., (2013), Kumar et al., (2016), Snehlata (2016) in River Yamuna. The maximum permitted turbidity limit by set by WHO (1984) for drinking water is 5 – 8 NTU and for other domestic purposes that should not exceed more than 25 NTU. Coming to water turbidity it ranged from 2.000 – 11.000 NTU at various sites with lowest value at the Control Site i.e., Site I, followed by Sites IV, V, III and highest at Site II. Turbidity of different samples also vary with the concentrations of the effluents with maximum turbidity being found at Site II because the site is located in the receiving end of the city with highest amounts of wastes and garbage through number of drains coming from the entire city is a clear cut indication of dissolved particles coming from most of the printing, dyeing and other chemical factories. Turbidity was also slightly higher at Site III because large number of people used to take bath and wash clothes with soap and also throw flowers and other materials used for daily worship. Besides, during festivity seasons millions of people take bath at this Site (Sharma, 1976). However, Turbidity showed positive relation with temperature, BOD, COD, DS and SS. However, the negative correlation was found with DO and the nitrates as has also been reported by a number of researchers (Thakur, 2001; Singh, 2003; Sharma, 2004; Singh et al., 2008; Parashar, 2011; Snehlata, 2016).

Oxygen is the most important factor that supports aquatic life. It is also essential for the oxidation and decomposition of the untreated organic compounds in water. In natural and waste water the level of Dissolved oxygen (DO) depends upon the physical, chemical and biological activities in water-bodies. Dissolved oxygen is a measure of the amount of oxygen freely available in water. The effect of waste discharge in a water body is largely determined by the oxygen balance of the system (Kumar et al., 2016). The main source of DO is atmospheric air and the oxygen coming from the photosynthetic activities of aquatic plants mainly phyto-planktons. But under conditions like eutrophication due to excessive algal growth DO level goes down drastically due to over-consumption of oxygen by the plants for their respiratory needs. Because of the low DO contents the BOD shoots up and the aquatic vegetation gets badly influenced. According to WHO (1984) the DO should not be lower than 6 mg/l (3 mg/l ISI standard). During present study the DO showed a highly fluctuating trend as it exhibited a strong negative trend with temperature, BOD, COD, ammonia, DS and SS. Depletion of DO is an index of increased organic pollution. In contrast to other sites at polluted sites the turbidity affects the penetration of light for the release of oxygen during photosynthesis by aquatic vegetation (Thakur, 2001; Sharma, 2004; Parashar, 2011; Snehlata, 2016). The water quality in respect to DO suggests that the Sites II and V were highly polluted as compared to other sites. Observations of DO levels showed lowest values at the Control Site i.e., Site I with an upward trend at Sites III, IV, II and a very high value at Site V. The present work is in accordance with the findings of other researchers (Kumar et al., 2011; Yadav and Rajawat, 2011; Gupta et al., 2013; Sharma et al., 2013; Singh et al., 2013; Kumar et al., 2016; Snehlata, 2016).

BOD is the amount of oxygen required by the aquatic species for their proper survival and by micro-organisms for decomposing and stabilizing the organic matter. B.O.D. determination is the best available single test for assessing organic pollution strength in a water body. Roughly BOD is proportional to the amount of organic waste present in the water body to be degraded aerobically (Kumar et al., 2016). In general, BOD along with COD gives a qualitative index of the organic pollution and helps

in deciding suitability of water for consumption. The maximum permissible limit for BOD is 5 mg/l (WHO, 1984) and the national standard stipulates a maximum value of BOD of 3 mg/l in a water body so that it can be used for bathing and drinking (CSE, 2007). BOD was found to be very high at Site V. It was found to have a very strong negative correlation with DO. Therefore, when DO was low the BOD was found to be high. BOD levels also showed very high values with lowest at Control Site i.e., Site I with an upward trend at Site IV and a slightly increased value at Site III and very-very high values at Sites II and V. It is interesting to note that BOD showed same trends as were observed with DO here also the maximum BOD values were observed at Site V and minimum at Site I. Findings of the present study are in concurrence with the observation made by other researchers (Kumar et al., 2011; Yadav and Rajawat, 2011; Gupta et al., 2013; Sharma et al., 2013; Singh et al., 2013; Kumar et al., 2016; Snehlata, 2016).

Chemical oxygen demand is the oxygen required for oxidation of organic matter by a strong chemical oxidant (Kumar et al., 2016). High COD shows high accumulation of organic waste in the river. Broadly COD exhibited similar trends to BOD. COD was high at Sites II and V as compared to other sites. The probable reason seemed to be the entry of polluted water containing detergents having alkyl benzene sulphonate and linear alkyl sulphonate, very fast, harmful and non-biodegradable chemicals and dyes which was found to be in accordance with the studies reported by a number of researchers (Sangu et al., 1983; Thakur, 2001; Sharma, 2004; Kumar et al., 2011; Parashar, 2011; Yadav and Rajawat, 2011; Gupta et al., 2013; Sharma et al., 2013; Singh et al., 2013; Kumar et al., 2016; Snehlata, 2016).

The above findings clearly showed undisputed fact that trends in DO, BOD and COD levels remained uniform and did not differ to a larger extent. Self-purification of rivers is one of their most remarkable characters which lead eventually to a large extent on biochemical reactions going on in the water brought about by the activities of micro-organisms (bacteria and phytoplanktons) which replenish sufficient oxygen utilizing the organic matter as food and breakdown complex compounds to simpler and harmless products.

Total dissolved solids (TDS) also serve as indicator of pollution. The quantity of T.D.S. is in general proportional to the degree of pollution. Sudden increase in the T.D.S. is often indicates pollution (Kumar et al., 2016).These add to turbidity and therefore, positively correlated with turbidity along with temperature, BOD and COD (Saxena and Chauhan, 1993; Thakur, 2001; Sharma, 2004; Parashar, 2011; Snehlata, 2016). TDS also showed positive trend with hardness. Since the ground water of Mathura depicts higher values of hardness, this might be the reason for high TDS. Comparatively TDS was higher at Sites II, III, IV and V due to the continuous mixing of industrial effluents. TDS was lowest in the Control Site i.e., Site I and highest at the Site V followed by Sites II, IV and III. The finding of the present research are in accordance with earlier researchers (Narayan et al., 2007; Yadav and Rajawat, 2011; Bhalerao, 2012; Gupta et al., 2013; Kumar et al., 2016).

Total suspended solids (TSS) showed almost a similar trend as that of TDS and were also found to be positively correlated with turbidity along with temperature, BOD and COD and hardness but showed a negative relation with that of DO. There seems to be an indirect negative relationship between TSS and DO involving the role of temperature and turbidity (Thakur, 2001; Sharma, 2004; Parashar, 2011; Snehlata, 2016). TSS was, however, higher at Sites II and V probably due to the accumulation of large amount of un-decomposed organic and inorganic wastes indicating positive correlation of TSS with BOD which is in corroboration with the observations made by Mathur et al., (1987), Shaji and Patel (1990), Saxena and Chauhan (1993), Thakur (2001), Sharma (2004), Parashar (2011), Snehlata (2016). TSS ranged from (211.667 – 1212.000 mg/l) with lowest values at the Control Site i.e., Site I and the highest at the Site V followed by the Sites II, IV and lastly Site III.

Further analysis of water revealed the presence of maximum amounts of electrolytes as such the conductivity was found to be very high (412.00 – 933.00 mg/l) with lowest in the Controls i.e., Site I followed by Sites IV, III and highest at the Site V. Similar findings have also been reported by other researchers (Kumar et al., 2011; Gupta et al., 2013; Kumar et al., 2016). Regarding the Anion (-ve ions) Chloride ions (Cl^-) the variation was quite observable with lowest being at the Control Site i.e., Site I followed upwardly at the Sites III, IV, V and the highest at the Site II. Higher values of these urban

sites are due to large amount of sewage discharges and increased rate of decomposition of organic matter because of high temperature during pre-monsoon season (Khanna and Bhutani, 2003). Chloride concentration in water indicates presence of organic waste particularly of animal origin or industrial origin (Kumar et al., 2016). Similar trends were also reported by Kumar et al., (2011); Dutta and Singh (2014); Saxena and Sharma (2014); Pradhan et al., (2015); Kumar et al., (2016). On the other hand, a reverse trend was observed with cations, i.e., Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}, where the maximum amount was found in water samples of Site V. The other ions like SO^{4-} matched with concentration of cations. The maximum value was found in water sample collected from Site-V (Sewage farm) which can be attributed to the discharge of domestic sewage and organic wastes in the study area (Parashar, 2011; Sharma et al., 2013).

Likewise, Cations (+ve ions) Calcium ions (Ca^{2+}), Sodium ions (Na^{+}), Potassium ions (K^{+}) and Magnesium ions (Mg^{2+}) also showed variable trends at various sites with lowest values at the Control Site i.e., Site I followed upwardly at Sites III, IV, II and highest at either Sites IV. Irregular increases of phosphate, calcium and magnesium may be due to addition of salt from detergents and other man made activities due to lack of effluent facilities and proper disposal system of wastewater in water bodies indicates pollution by domestic sewage and agriculture run-off specially phosphate fertilizers (Sharma et al., 2013; Kumar et al., 2016). Hardness showed a positive correlation with temperature, DS and SS as higher temperature increases the density of ions in the water. Hardness was found to be high at all sites but comparatively was higher at Sites II and V while hardness at Sites III and IV did not show sharp differences. The probable reason for the high degree of salinity might be due to the existing higher levels of salts of Ca, Mg, Na and K in the ground water along with the various chemical industries discharging their effluents and huge quantity of untreated city sewage in river water (Sharma, 1976; Saxena and Chauhan, 1993; Thakur, 2001; Singh, 2003; Sharma, 2004; Singh et al., 2008; Kumar et al., 2011; Parashar, 2011; Gupta et al., 2013; Sharma et al., 2013; Kumar et al., 2016; Snehlata, 2016).

Total alkalinity was found to be lowest at Site II followed by Sites I i.e., the Control Site, IV, III and the highest at Site V. It is well-established fact that the alkalinity of water is mainly due to the presence of Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, NH^{4-} and Fe^{2+}/Fe^{3+} combined either with carbonate or occasionally hydroxides. The zonal variation clearly reveals the different status of effluents at different sites. The total organic and inorganic solids present in industrial and sewage effluents affect the turbidity, conductivity and alkalinity, as highest amount of TS was observed at Site V and lowest at Site I. A greater degree of difference was observed at different sites. A greater quantum of total solids has shown resemblance with above discussed parameters. As recorded earlier a similar finding was observed with TDS where a higher magnitude of TDS was recorded at Site V surprisingly enough followed by Site II because a huge amount of effluents are directly thrown by various industries and city sewage through a number of drains. The present findings are in conformity with the observation made by earlier researchers (Narayan et al., 2007; Kumar et al., 2011; Bhalerao, 2012; Gupta et al., 2013; Kumar et al., 2016).

Organic nitrogenous matter is destroyed by microbial activity with the production of ammonia. Higher concentration of ammonical nitrogen occurs in water polluted with sewage or/and industrial wastes containing nitrogenous contents. Nitrogen compounds serving as nutrients for aquatic fauna (Algae) causes eutrophication of water-bodies. A very high amount of ammonical nitrogen contents were observed at Sites II and V in comparison to other sites which might be due to high sewage mixing which showed these sites to be the worst affected with pollution with low DO, very high BOD and COD at these sites. Ammonical nitrogen showed negative relation with DO as the ammonia production takes place from non-oxidized accumulated garbage (Sharma, 1976; Thakur, 2001; Sharma, 2004; Parashar, 2011; Snehlata, 2016). Nitrate nitrogen shows the state of oxidation of nitrogenous compounds present in polluted water. Presence of higher nitrate contents in water are generally indicative of pollution (Kumar et al., 2016) suggesting the presence of high DO and low BOD. The nitrate contents exhibited a direct positive correlation with DO (Sharma, 2004; Parashar, 2011; Snehlata, 2016) but direct negative relation with ammonia (Thakur, 2001; Sharma, 2004; Parashar, 2011; Snehlata, 2016). Ammonical Nitrogen (NH_3-N) was not detected at Control site i.e., Site I, however,

the lowest amount was found at Site III followed upwardly at Sites IV, II and highest at Site V with. Nitrate Nitrogen (NO_3-N) at Control site i.e., Site I was the least followed upwardly at Sites III, IV, II and highest at Site V. Higher values were observed at Site-II and Site II because of mixing of various effluents from industries and other waste material. Similar observations were made by Parashar (2011); Gupta et al., (2013); Sharma et al., (2013); Kumar et al., (2016); Snehlata (2016).

Over the last few years, the water quality of Yamuna has deteriorated despite huge expenditure and efforts put by the government. One of the potent effects of the polluted water is occurrence of heavy metals. Which are harmful and toxic at high concentrations affecting aquatic animals as well as human life (Christopher et al., 2012). TERI (2012) had conducted research work which clearly showed toxic metals in the water at several locations regarded Yamuna, the poisoned river. Regarding the heavy metals in the present study none were detected in the **Control site** i.e., at **Site I** whereas variable concentration of *Fe, Hg*, *Cr*, *Cd*, *Pb* and *As* were detected in the **effluent samples** from the **Sites II**, **III**, **IV** and **V**. *Total Iron* at **Control site** i.e., **Site I** and at **Site III** were the *least* followed *upwardly* at **Sites IV**, **II** and *highest* at **Site V**. *Mercury* (Hg) was detected in *least concentration* at the **Site IV** followed *upwardly* at **Sites III**, **II** and *highest* at **Site V**. Likewise, *Chromium* (Cr) was detected in *least concentration* at the **Site IV** followed *upwardly* at **Sites III**, **II** and *highest* at **Site V**. *Cadmium* (Cd) was detected in *least concentration* at the **Site IV** followed *upwardly* at **Sites III**, **V** and *highest* at **Site II**. *Lead* (Pb) was detected in *least concentration* at the **Site IV** followed *upwardly* at **Sites III**, **II** and *highest* at **Site V.** Lead is highly toxic metal used in various industries manufacturing PVC, plastic, batteries, paints etc., and as antiknock agent in automobile fuels. Normally its concentration in normal water is very less and permissible limit is 0.05 mg/l (Weller House, 1978) and 0.1 mg/l (ICMR, 1975). *Arsenic* (As) was detected in *least concentration* at **Site III** followed upwardly at **Sites IV**, **V** and highest at **Site II**. Average heavy metal concentration at different locations in the river water varied in the order of **Cd>As>Fe>Pb>Cr>Hg.** The reason for these toxic heavy metals present in river water is due to discharge by sari printing, silver processing and other industries using various dyes and chemicals containing these heavy metals. Similarly, heavy metals have also been reported by several researchers in Yamuna River water which is suffering from heavy pollution load and almost considered as a dead river with discharge of untreated effluents from industrial and city sewage laden with heavy metals further added from agricultural runoff and leaching from the soil (Singh, 2001; Thakur, 2001; Parashar, 2011; TERI, 2011; Kaur and Rani, 2006; Mishra, 2010; Christopher et al., 2012; Kaur and Mehra, 2012; Rai et al., 2012; Sehgal et al., 2012; Dhillon et al., 2013; Kaur et al., 2013; Malik et al., 2014; Singh et al., 2014; Rai and Bajpai, 2016; Rai et al., 2016; Tilwankar et al., 2016; Alam et al., 2017).

CONCLUSION

An increasingly greater concern for water quality problems has been shown for the past few decades due to steep rise in population in cities and urban areas. Unprecedented and rapid industrial development, un-mindful use of natural resources and building of huge urban complexes are responsible for changing the natural pattern creating several environmental pollution problems causing water quality deterioration. The present study was an effort and aimed at detailed study of potential water quality problems in the light of industrial and urban development in Mathura with an attempt elsewhere to see its impact on plant growth and development vis-à-vis on animal and human population, especially agricultural crops of the region so that the quality of city and industrial effluent water of Yamuna River is best utilized for irrigation to raise higher crop yield. It is, thus, concluded that Yamuna river water, receiving various drains dumping their contents, is grossly polluted due to city sewage, un-treated domestic wastes and also industrial effluents containing various salts including heavy metals as most of the parameters are found above the permissible limit which have extremely dangerous-life-threatening effects on aquatic biota and through food chain to animals and human population. The study revealed that the water of River Yamuna except the control site (Site I Water Works) is highly contaminated at all the sites (Sites II to V) during the course of study and it is unfit for consumption, domestic and irrigation purposes. Though, tremendous efforts

have been put up with huge money spent by the Indian Government to prevent alarming levels of pollution in the River Yamuna. Despite such efforts, the pollution is increasing drastically and is affecting life, cattle and aquatic species. Some steps are needed urgently to improve the quality of river Yamuna. The present investigation clearly showed that if proper measures are not taken to clean the river it is going to die and along with we shall also be doomed. Some effective measures are urgently needed to stop on going deterioration and improve water quality of Yamuna River. A periodic survey is also recommended to maintain the water quality of the river. This is important as Yamuna is a national concern.

RECOMMENDATIONS

Our Recommendations rather Suggestions include:

- An environmental awareness coupled with individual contribution today can make all the difference tomorrow.
- Open defecation near the river banks should be strictly stopped along with cattle bathing and bathing clothes by washer men be prohibited.
- Development of clean ghats (bathing areas) and proper bathing facilities must be provided.
- Stoppage of direct dumping of religious flowers and other material into the river is strictly followed.
- Sewage should be used for bio-gas production to light the streets and households.
- It should be made mandatory for industries to treat their effluents before draining them out into the river.
- Be vigilant that factory discharging its effluents into the river is sucking the water out of your future.
- Technological advances, peoples' participation and favourable water use and allocation policies need to be put in place for sustainable use of such effluent rich water.

But not the least all of us must realize that: *'Water is truly the elixir of life and pretty soon it will run out'.*

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